Jones & Korsmo

The Measurement of Water
By Means of Vertical Jets

Municipal & Sanitary Engineering
And Civil Engineering

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THE MEASUREMENT OF WATER BY MEANS OF VERTICAL JETS

BY

BRUCE LEROY JONES

AND

AMUND MARIUS KORSMO

THESIS

For the Degree of

BACHELOR OF SCIENCE

IN MUNICIPAL AND SANITARY ENGINEERING BY BRUCE LEROY JONES

IN CIVIL ENGINEERING BY AMUND MARIUS KORSMO

IN THE

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

Presented June 1909

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June 1, 1909

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

BRUCE LEROY JONES

ENTITLED THE MEASUREMENT OF WATER BY MEANS OF VERTICAL JETS

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Municipal and Sanitary Engineering.

Melvin L. Enger
Instructor in Charge

APPROVED: A N Talbot

HEAD OF DEPARTMENT OF Municipal and Sanitary Engineering

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Melvin L. Enger
Instructor in Charge

APPROVED: John P. Brooks

HEAD OF DEPARTMENT OF Civil Engineering

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No. I.

3 IN ORIFICE ON 12 IN SHORT TUBE
3.7 FT. JET.

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The Measurement of Water by Means of Vertical Jets.

GENERAL IDEAS OF WATER MEASUREMENT. Flowing water is measured in several ways, in open channels, orifices and weirs. In any of these methods the factors involved are (1.) the area of cross section of flowing water perpendicular to the direction of flow. (2) the head producing the flow. When the velocity is constant throughout the cross section, the measurement of flow is simple, but when not constant certain coefficients peculiar to the conditions have to be incorporated in the theoretical formula.

The cross section at any point can be gotten by direct measurement. The head at any point, when water is at rest, is the vertical distance from the point to the surface of the water. This is called pressure head. When water is allowed to flow, beside this pressure head, there is also a head which has produced the flow, called velocity head. The total head at any point is therefore the pressure head plus the velocity head. When the discharge is into the atmosphere the head is velocity head, for the pressure on unit area due to atmospheric pressure at point of discharge is equal to unit pressure at surface, and pressure is transmitted equally in all directions. Thus the water discharged from a vertical jet has only velocity head and neglecting friction of the air and falling of jet upon itself, the water will rise to a height equal to the velocity head at the point of discharge. The theoretic formula is therefore easily derived and an actual formula can be gotten by applying coefficients to this theoretical formula.

From the above discussion the following conclusions can be drawn.

1. For any efficient measuring device either head or area of flow must be constant or one must vary directly with the other. This

latter case is that of the weir.

2. The head must be such as can be easily measured and the measurement is more simple if it is entirely pressure head or entirely velocity head. In the case of the nozzle the head is partially pressure head and partially velocity head. A small vertical orifice in the side of a large tank is an example of pressure head while the vertical jet, neglecting friction of the air and the falling of the jet upon itself, is an example of velocity head.

3. There should be as slight disturbance of flow as possible. This is necessary in order that the velocity may not be changed at any portion of the area of cross section.

THEORETICAL COMPARISON OF VERTICAL JET AND WEIR. The comparison of the relative value of these two devices must be (1) a comparison of the ease and cost of construction of each and (2) the relative accuracy of each.

1.- A comparison of the construction and cost of the two involve the use which is made of them. If the water flowing in a small open channel is to be measured, the simplest way is to construct a weir across the channel and hold back the flow enough to give the extra drop required for the weir. Care would need be taken to make the crest of the weir straight and level. This is not necessarily difficult, but to measure the same with a vertical jet a large collecting box would have to be constructed and the cost of this combined with the cost of the necessary packing up of the water would make the jet impracticable. In cases where water is flowing through a closed pipe, as in public water supplies and duty tests of pumping engines or where water is flowing in open channels where there is plenty of fall and the water can be made to flow into a pipe as is the case in irrigation projects in the Western part of the United

No. 2.

3 in. Orifice on 12 in Short Tube
3 ft Jet. Trough Carrying Water
Over 3 ft. Weir.

States, the vertical jet is more easily constructed. All that is needed in this case is a short section of vertical pipe, a set of reducers, expanded section and baffles to equalize flow and an orifice plate on top of a short tube. It is very likely that the jet will soon come into common use in connection with commercial tests of pumping engines because of the ease of building and of transportation. The writers are informed that the Vertical Short Tube is already in use in these tests by the Illinois Central Railroad Company.

2. The theoretical formula for a rectangular weir is $Q = \frac{2}{3} b \sqrt{2g}\, H^{3/2}$ where b is width of crest of weir, g is acceleration due to gravity, and H is the head on crest of weir. The theoretical formula for a vertical jet is $Q = a\sqrt{2g}\, H^{1/2}$ being easily derived from $Q = av$ and $v = \sqrt{2gH}$ a is area of tube or orifice, g is acceleration due to gravity, and H is head of height of jet. It is readily seen that when any variable quantity is raised to a power the resulting error is very much increased. Let r be probable error of measurement in H and R the proportionate error in Q.

Then for the weir

$$Q_1 = \tfrac{2}{3} b \sqrt{2g}\, H_1^{3/2}$$

$$1. \quad Q = K H_1^{3/2}$$

$$Q_1 \pm R_1 = K (H_1 \pm r_1)^{3/2}$$

$$= K \left[H_1 \left(1 \pm \frac{r_1}{H_1}\right) \right]^{3/2}$$

$$2. \quad Q \pm R_1 = K H_1^{3/2} \left(1 \pm \tfrac{3}{2} \frac{r_1}{H_1} + \text{----etc}\right)$$

$$1. \quad \underline{Q_1} = \underline{K H_1^{3/2}}$$

Subtracting 1 from 2

$$\pm R_1 = K H_1^{3/2} \left(\pm \tfrac{3}{2} \frac{r_1}{H_1} + \text{-----} \ etc\right)$$

$$\pm \frac{R_1}{Q_1} = \pm \tfrac{3}{2} \frac{r_1}{H_1}$$

For the jet

$$Q_2 = a\sqrt{2g}\, H_2^{1/2}$$

$$3. \quad Q_2 = K H_2^{1/2}$$

$$Q_2 \pm R_2 = K (H_2 \pm r_2)^{1/2}$$

$$= K \left[H_2 \left(1 \pm \frac{r_2}{H_2}\right)\right]^{1/2}$$

$$4. \quad Q_2 \pm R_2 = K H_2^{1/2} \left(1 + \tfrac{1}{2} \frac{r_2}{H_2} + \text{-----} \ etc\right)$$

$$3. \quad \underline{Q_2} = \underline{K H^{1/2}}$$

Subtracting 3 from 4

$$\pm R_2 = K H_2^{1/2} \left(1 \pm \tfrac{1}{2} \frac{r_2}{H_2} + \text{------} \ etc\right)$$

$$\pm \frac{R_2}{Q_2} = \pm \tfrac{1}{2} \frac{r_2}{H_2}$$

A convenient example of the above is as follows - An 8 in. vertical jet under head of 4.25 feet will discharge practically the same as a 3 foot contracted weir under head of .520 feet as determined by experiment.

Then $\quad Q = Q_2 \ , \ H_1 = .520 \ , \ H_2 = 4.25$

and $\quad \frac{R_1}{Q_1} \div \frac{R_2}{Q_2} = \tfrac{3}{2} \frac{r_1}{H_1} \div \tfrac{1}{2} \frac{r_2}{H_2}$

$$\frac{R_1}{R_2} = 3 \frac{r_1 H_2}{r_2 H_1} = 3 \frac{4.25\, r_1}{.520\, r_2} = 24.5 \frac{r_1}{r_2}$$

The head on jet can be read to .01 of a foot and head on weir can be read to .001 of a foot. Then $10\, r_1 = r_2$

$$\frac{R_1}{R_2} = 24.5 \frac{r_1}{r_2} = 24.5 \frac{1}{10} = 2.45$$

which shows the jet to be approximately two and a half times as accurate as the weir.

No. 3

Same as No 2 With Movable Section of Trough Raised to Allow Water to Fall into Measuring Pit

Under low heads the jet is more stable and is measureable to .005 of a foot while the weir is inaccurate under the same discharge o account of surface tension etc, and the jet would then be about five times as accurate as the weir and probably more than this because of interference of flow by surface tension etc.

PURPOSE OF EXPERIMENTS. The tests were made with the idea of calibrating accurately certain apparatus and not with the idea of designing additional apparatus. It was decided after a study of the results obtained by Messrs Cutler and Marsden that the design of apparatus shown on plates 3 and 5 was satisfactory and the object of these experiments is to accurately determine the discharge and coefficients of discharge for this particular apparatus with different sizes of orifices varying from 5 in. to 10 in. It was decided to measure the discharge by displacement rather than by means of a weir which in itself is very inaccurate and a method of accurate measurement of time of flow is necessary.

AUTHORITIES. The chief experiments that have been made with the vertical jet have been made by the U. S. Hydrographic Survey. Laboratory experiments have been conducted by F. E. Lawrence and P.L. Braunworth of Cornell University, by C.V. Seastone of the Uni. of Illinois and by S.G. Cutler and R.D. Marsden of the Uni. of Illinois. The experiments made at Cornell and those by Mr. Seastone were performed with special apparatus which does not appear to be practical. The apparatus recommended by Cutler and Marsden and designed by Professor Talbot was used because (1) it gives a fairly uniform flow throug orifice where a short length of vertical pipe is attached to a length of horizontal pipe which is necessarily the case in actual practice and (2) beaause it is practical beaause of first cost, ease

of transportation and ease of operation. The apparatus and measurement of head used by the above mentioned was used but a different method of measurement of discharge and time was devised. The accessory apparatus necessary for the latter is explained later in paragraphs on Methods of Measurements.

GENERAL APPARATUS. The experiments were made in the Hydraulics Laboratory at the University of Illinois. The equipment used in the tests is shown on plate 1. and consists of one Duplex Pump, capacity of 2200 gallons per minute, one Duplex Pump capacity of 1000 gallons per minute, one centrifugal pump, capacity of 1800 gallons per minute, a stand pipe 6 feet in diameter and 60 feet high, a pump sump 12 feet in diameter, measuring Pit with cross section of approximately 180 sq. feet, 3 foot contracted weir, 3 foot open channel, and 3 foot suppressed weir. The jet was located in the North West corner of the laboratory in the measuring pit above mentioned. Leading to the jet there were two connections to the stand pipe, each one being thru a 12 in. pipe line. Each one of these had a valve near the stand pipe and another valve was located near the jet. The water discharged into the pit, flowed over the 3 foot contracted weir at the East end of the pit, thru the open channel over the 3 foot weir and thence into the sump. The water was pumped from the sump into the standpipe and flowed thru the 12 in. pipe to the jet making the operation continuous. A 12 in. drain pipe lead from the South East corner of the Measuring pit to a second pit ant thence into the sump, by means of which the pit could be emptied. The level of water in the standpipe was kept at any desired head by adjusting the weight on governing lever of engine. This head was ordinarily 17 feet at the standpipe or 32 feet at the jet. Heads as high as 60 feet at the standpipe or

75 feet at jet were obtainable. The height of water in pit and the height of water above crest of contracted weir was measured by means of hook gage on Plate 1.

METHODS OF MEASUREMENT. In order that the discharge in cubic feet per second be accurately determined it is necessary (1) that the water flowing in a certain time be collected in a pit and measured by displacement and (2) that accurate measurement of the time of flow into pit be made.

The first of these was gotten by calibrating the pit using known weights of water, reading hook gage after each known weight was let into pit, and plotting calibration curve of pit with reading of hook gage in feet as abscissae and quantity of water reduced to cubic feet as ordinates. The calibration curve for measuring pit is shown on curve 7. With hook gage reading before and after any discharge the amount of water discharged into pit can be gotten from calibration curve.

Accurate measurements of time was gotten by means of the accessory apparatus shown on Plate 5. This consists of a collecting box, a movable section of trough and a fixed trough, the latter extending over the three foot contracted weir and thus discharging into the open channel. A picture of the apparatus is shown in views 2 and 3. The method was as follows - With the movable trough down so that the water flowed over the weir and not into the pit, the valve controlling the jet was adjusted so that the required head was secured on jet. The reading of hook gage was then taken. The movable section of trough was then quickly raised and at the same time a stop watch was started. The water was then allowed to flow into the pit until it was nearly full when the movable trough was let down, the stop watch being

No. 4.

8 IN ORIFICE ON 12 IN SHORT TUBE
2.7 FT. JET

stopped at the same time. The reading of the hook gage was then taken and the drain opened to allow water to flow from pit. In this way the time could be gotten to the nearest $\frac{1}{5}$ or $\frac{1}{4}$ second.

The measurement of the head on the jet was made by means of sighting rods. The zero reading of the orifices was first gotten by holding a rule up from the plane of the orifice and reading the rod over the top of the rule and subtracting the length of the rule from this rod reading. The head at any time was then gotten by subtracting the zero head from the reading over the top of jet. The sighting rods are shown in the pictures and are simply rods graduated to feet, tenths, and hundredths of a foot. The rod at which the observer placed his eye was eleven feet from the jet and the other rod was three feet on the opposite side of the jet and thus any error in height of observers eye was decreased to 3/11 of its real amount. In this way accurate readings to .01 of a foot could be gotten with comparative ease.

DESCRIPTION OF APPARATUS. A condition which would nearly always be present in actual practice would be a section of horizontal pipe, an elbow turned upward, and the meter on the top of this. It can readily be seen that with this arrangement the water would tend to follow the farther side of the vertical part of the meter and thus the greater part of flow would be on that side and the discharge would vary across the area of cross section. As this is very undesirable it is necessary to include a set of expanded section reducers, baffles, short tube and orifice plate to equalize the flow across the section. These facts being observed the apparatus was as follows - A vertical section of pipe containing 12 in. valve with 6 feet of vertical pipe below this an elbow and 4 feet of horizontal pipe, another elbow, short section of 12 in. pipe, steel baffle with 7/8 in. holes 1 in. apart center to

center, expanded section, wooden baffle, with 5/8 in. holes 1 1/8 in. center to center, contracted section, 12 in. short tube and orifice plate bolted on top of this short tube. The weight of the apparatus is 625 pds. A drawing of the apparatus is shown on Plates 3 and 5 and an idea of the appearance of the same can be gotten from View No. 5.

EXPERIMENTS MADE. Experiments were first made on a 6 in. orifice on 12. in. short tube, the orifice plate having a coat of paint on the lower face. It was thought that perhaps that the condition of the lower face of the orifice plate might effect the coefficients of discharge and in order to find out the real facts, the tar paint was removed from the lower face of the plate and same was polished with sandpaper. Readings were then taken with six in. orifice and the results were practically the same as the previous ones. The same was repeated with the 8 in. orifice on 12 in. short tube with the same results. The results of these experiments are shown on curves 3 and 4. Although there was no appreciable difference in the discharge coefficients with plates painted and polished, it was decided to perform the remaining experiments without any paint on the lower face of orifice plate.

Experiments were then made on 3, 4, 6, 8 and 10 in. orifices all on 12 in. short tubes. All orifices up to and including 10 ins. gave a very good jet, the distribution of velocity thru out the cross section being good but orifices above 10 in. gave poor jets. The fact that the smaller orifices give the best distribution, of flow is probably due to the fact that there is not enough contraction to equalize the flow when a large orifice is used. The views give an idea of the relative condition of flow of the 3 in. and 8 in. orifice

jets. The 2 in. orifice was tried but it was difficult to make it break, it falling on itself and the writers recommend that the 3 in. orifice be the smallest used. The discharges from the 10 in. orifice were measured over the 3 foot contracted weir, the weir first having been checked by means of discharges from the 8 in. orifice. The weir discharges as computed from Smith's formula checked very good with the same as measured by means of the 8 in. jet. The data for the checking is shown on Table No. 5.

DISCUSSION OF RESULTS AND CONCLUSIONS,

COEFFICIENTS. The coefficients were computed from the formula $Q = Ca\sqrt{2g}\,H^{1/2}$ or $c = \frac{Q}{a\sqrt{2g}\,H^{1/2}}$ where Q is water discharged in cubic feet per second, a is area of orifice, g is acceleration due to gravity = 64.4 feet per second and H is head on jet.

The coefficient curves are plotted for the jet condition only. The weir condition is explained in Messrs Cutler and Marsden's Thesis and is as follows - Under low heads the space below orifice plate and outside of diameter of orifice is filled with water and the water in flowing out follows the edges of the plate and instead of acting as a jet it acts as a weir, the direction of flow being perpendicular to the axis of the tube. As the head increases, at a certain height the direction of flow becomes parallel to the axis of the tube and the flow is of the jet form.

It is seen that the coefficient curves are not straight lines but are slightly concave downward, the same being more apparent in the case of the smaller orifices. This variation is similar to the variation of coefficients for a weir and might be explained as follows- As the head increases the friction of the air grows less in proportion to the force of the water and the coefficients tend to increase. As

[illegible]

[illegible] were measured over the 8 foot contracted weir, the weir [illegible] [illegible] checked by means of [illegible] from the 8 in. [illegible]. The [illegible] discharge as compared from [illegible] formula checked very [illegible] the [illegible] as measured by means of the 8 in. jet. [illegible] checking is shown on Table No. 5.

CONDITION OF RESULTS AND CONCLUSIONS.

COEFFICIENTS. The coefficients were computed from the formula [illegible] where [illegible] is water discharged [illegible] per second, [illegible] area of orifice, [illegible] is acceleration due to gravity [illegible] feet per second and [illegible] is head on jet.

The coefficient curves are plotted for the jet condition only. The weir condition is [illegible] in [illegible] and [illegible] and is as follows - Under [illegible] heads the space below orifice plate and outside of diameter of orifice is filled with water and the water in flowing out follows the edges of the plate and instead of [illegible] as a jet it acts as a weir, the direction of flow being perpendicular to the axis of the tube. As the head increases, at a certain height the direction of flow becomes parallel to the axis of the tube and the flow is of the jet form.

It is seen that the coefficient curves are not straight lines but are slightly concave downward, the same being more apparent in the case of the smaller orifices. This variation is similar to the variation of coefficients for a weir and might be explained as follows: As the head increases the friction of the air grows long in [illegible] to the force of the water and the coefficients long in increase. As

the head is increased the weight of the water falling back on the jet becomes greater and over balances the tendency of the coefficients to increase and causes them to decrease. It can be seen that this would be more apparent in the case of a smaller orifice because a little interference would affect them more than it would a larger orifice jet.

The discharge curve is that of a parabola, the formula for the discharge being a parabolic equation. Variations in the coefficients may slightly change the form of curve but it is still approximately a parabola.

RESULTS OBTAINED AND RECOMMENDATIONS. An idea of the results obtained can be gotten by means of the curves of discharge and discharge coefficients.

To get the best results it was found that (1) as small an orifice as will give the discharge required should be used since the smaller orifices give better distribution, it being entirely impracticable to use orifices larger than 10 in. because of this unequal distribution (2) the jet should be used with heads which will give the jet condition. The weir condition is explained on page 11. Also the jet should not be used above a certain maximum head because of difficulty of measurement due to jet breaking up etc. The heads recommended are

Size of Orifice	3"	4"	6"	8"	10"
Size of Tube	12"	12"	12"	12"	12"
Min. Head	1.0'	1.2'	1.4'	1.4'	1.6'
Max. Head	6'	5'	4.5'	4'	3'

Heads near minimum are recommended as these give steadier conditions of flow and are more easily read. (3) The throttling valve should be placed near jet and jet should be throttled at this point almost entirely for this serves to prevent the pressure fluctuations or surging in a long pipe. (4) The orifice plate should not be painted on lower face, but should be smooth and be kept free from any rust tubercles which tend to form. These can readily removed. (5) The orifice plate should be firmly bolted against the top of the short tube, because if it is not, water will be forced out at this point and this will greatly affect the discharge and discharge coefficient. (6) The size of orifice to be used for any discharge can be gotten from the following table:

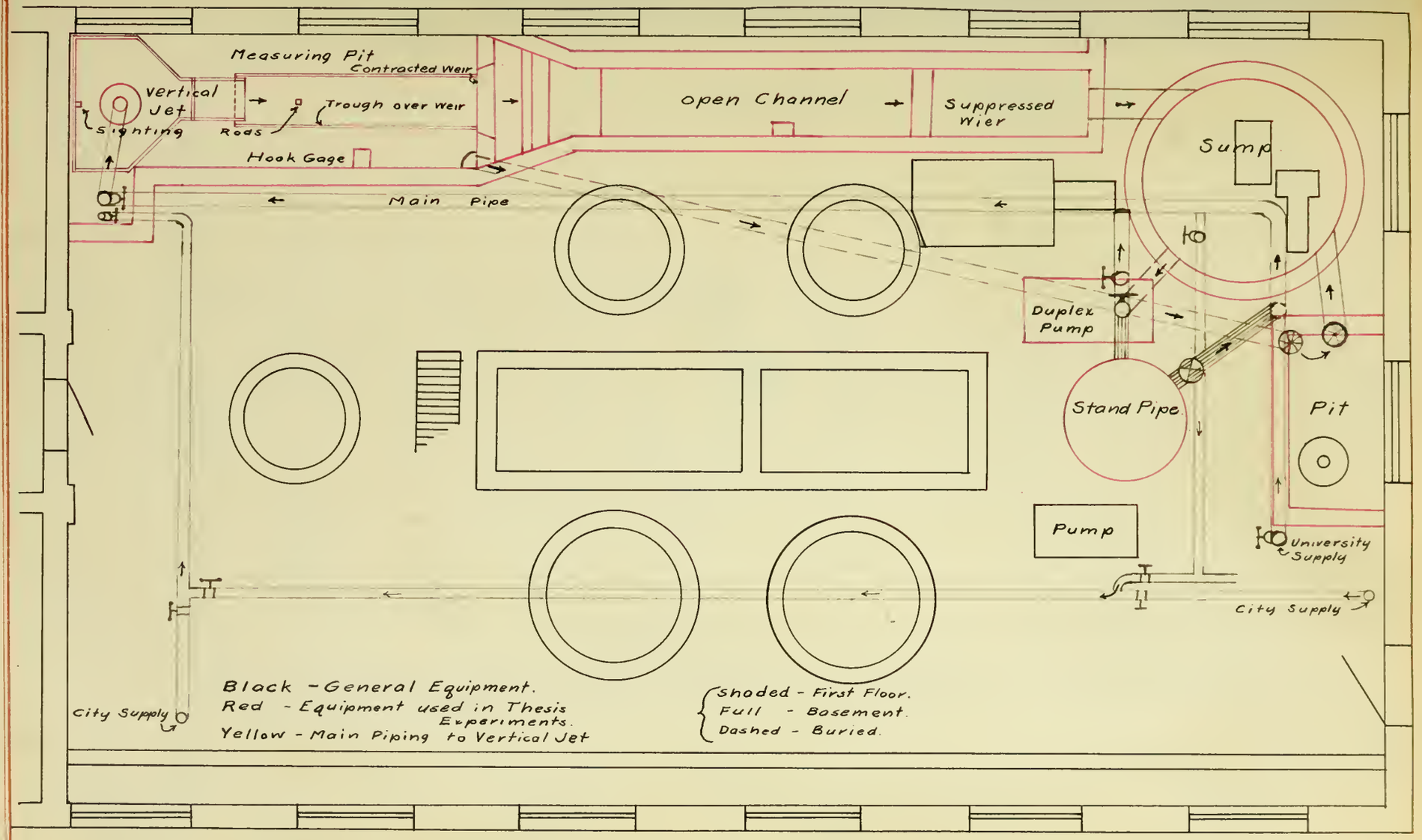
Min. Discharge in galls. per day.	150,000	300,000	700,000	1,360,000	2,400,000
Max. Discharge in galls. per day.	300,000	600,000	1,300,000	2,400,000	3,400,000
Min Discharge in Cu. ft. per Sec.	.282	.464	1.08	2.105	3.715
Max. Discharge in cu. ft. per Sec.	.464	.928	2.01	3.715	5.26
Size of Tube	12"	12"	12"	12"	12"
Size of Orifice	3"	4"	6"	8"	10"

No. 5.

6 IN. ORIFICE ON 8 IN. SHORT TUBE
4 FT JET.
COLLECTING TROUGH REMOVED

BASEMENT AND PIPING PLANS, HYDRAULICS LABORATORY, UNIV. OF ILLINOIS - 77'-6" × 46'-6".

PLATE I



SCALE $\frac{1}{8}$" = 1 ft.

PLATE 2

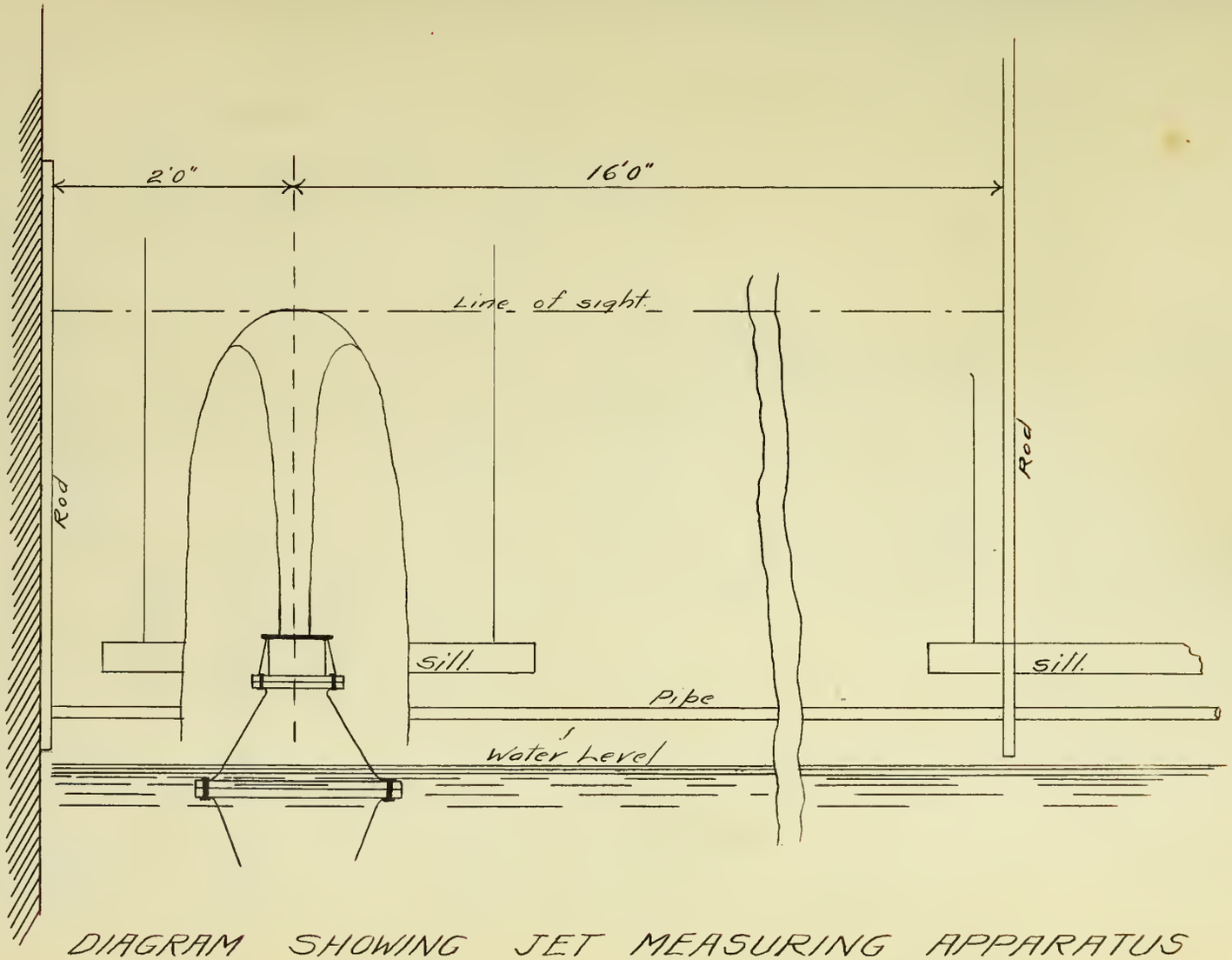
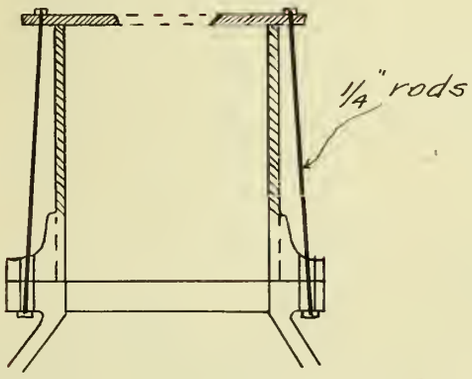


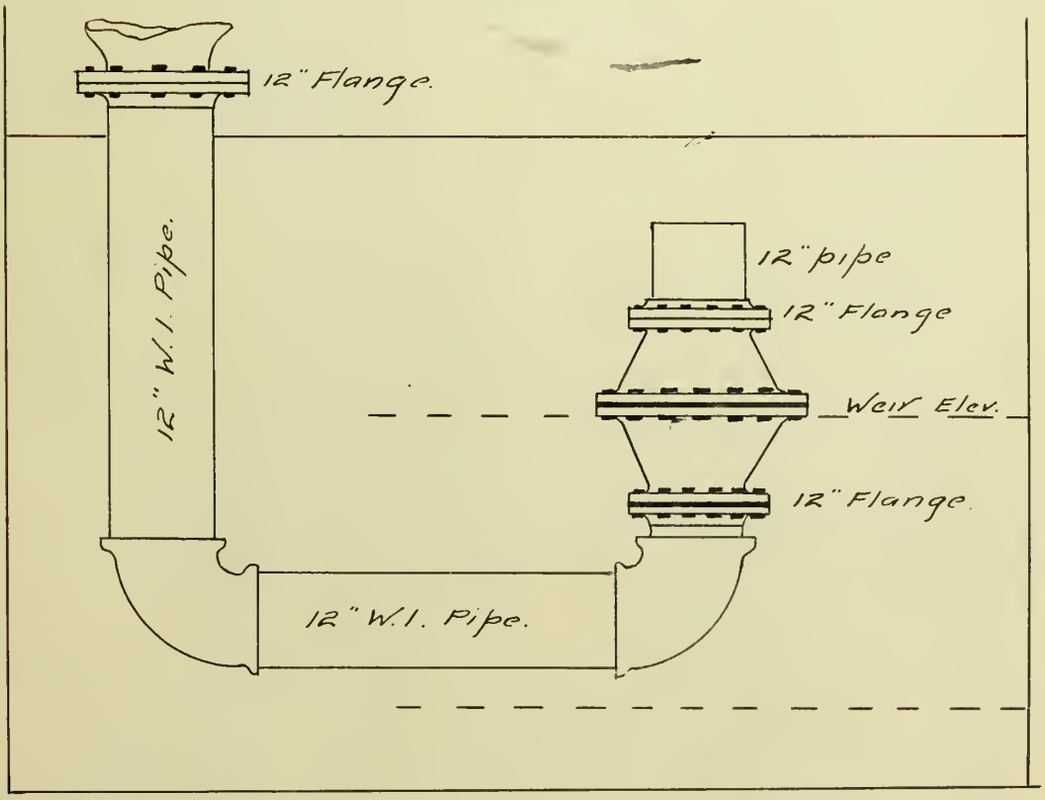
DIAGRAM SHOWING JET MEASURING APPARATUS
With Collecting Box and Trough Removed.

PLATE 3

6 IN ORIFICE ON 8 IN REDUCER

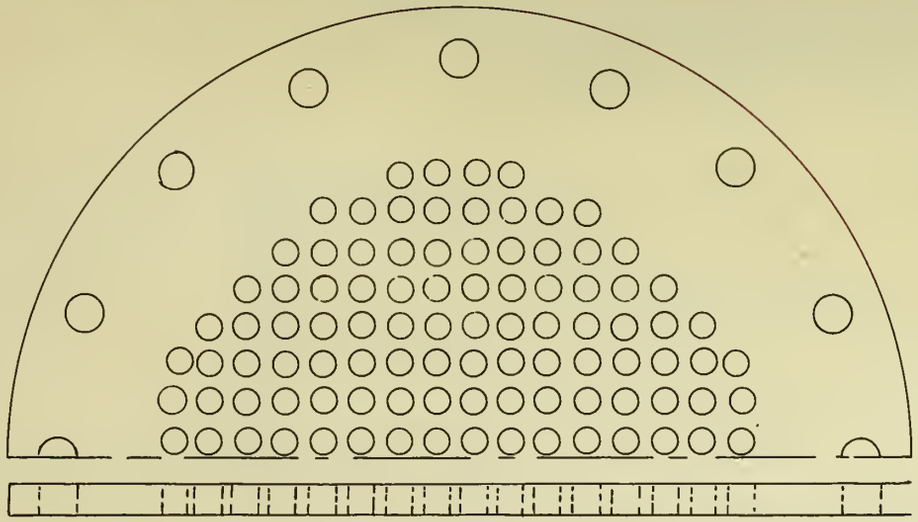


6 IN ORIFICE ON 8 IN. SHORT TUBE

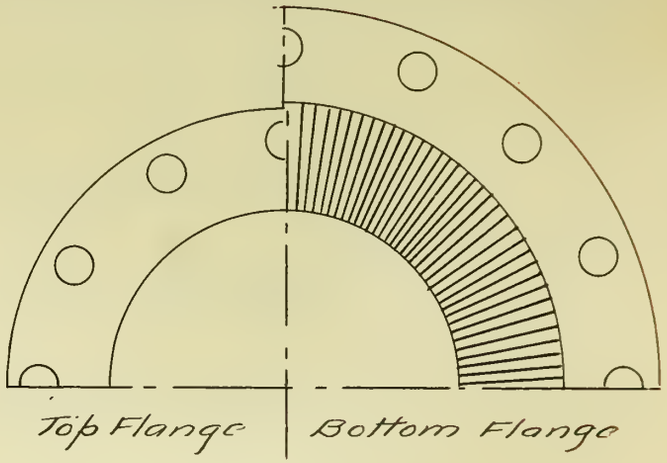


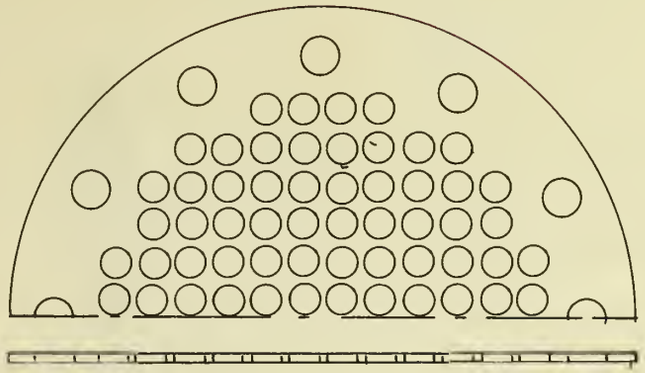
APPARATUS SHOWING 12 IN SHORT TUBE IN USE

PLATE 4.

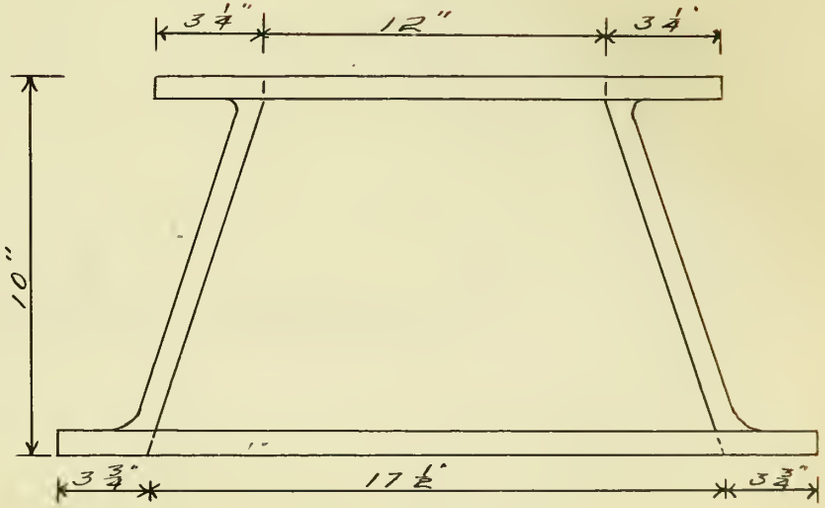


WOODEN BAFFLE
Holes $\frac{5}{8}$"d. $1\frac{1}{8}$" c. to c.





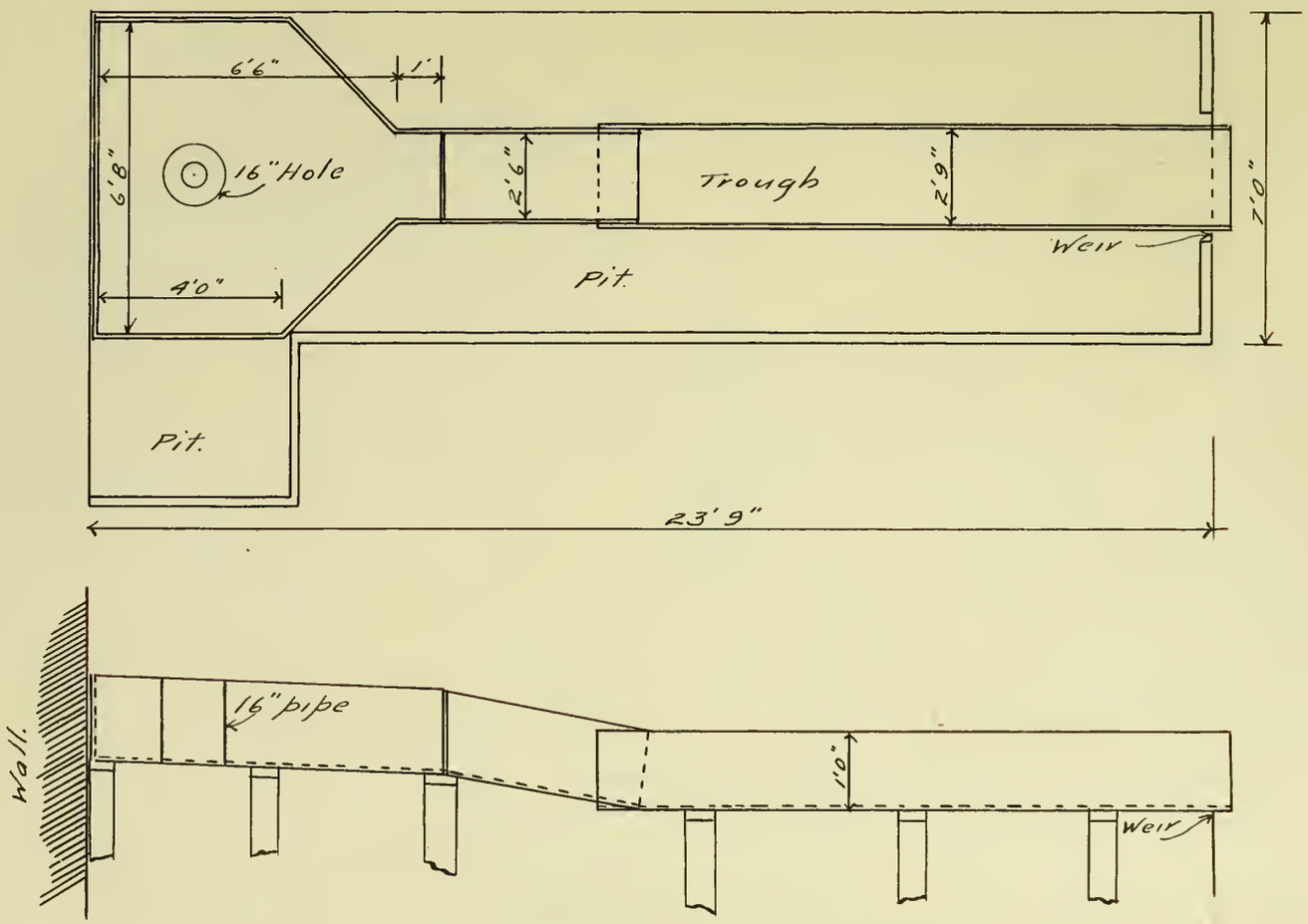
STEEL BAFFLE
Holes $\frac{7}{8}$"d. 1" c. to c.



REDUCER
side elevation

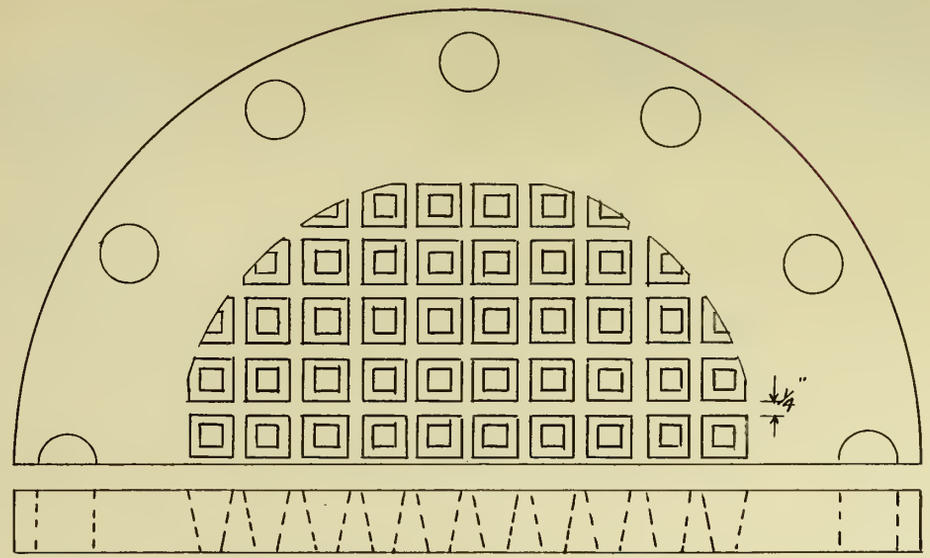
DETAILS FOR 12 IN. JET-REDUCER.

PLATE 5



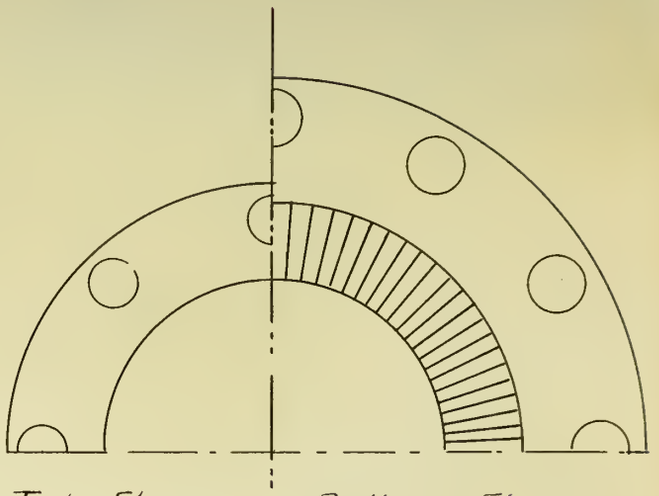
SKETCH SHOWING COLLECTING BOX AND TROUGH

PLATE 6

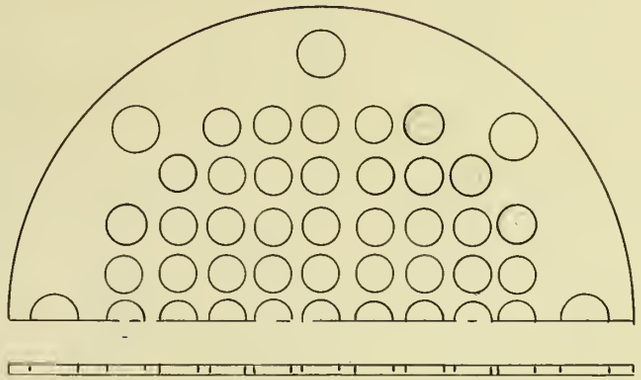


WOODEN BAFFLE

Holes 1"□ tapering to 5/8"□ Holes 1 1/4" C. to C.

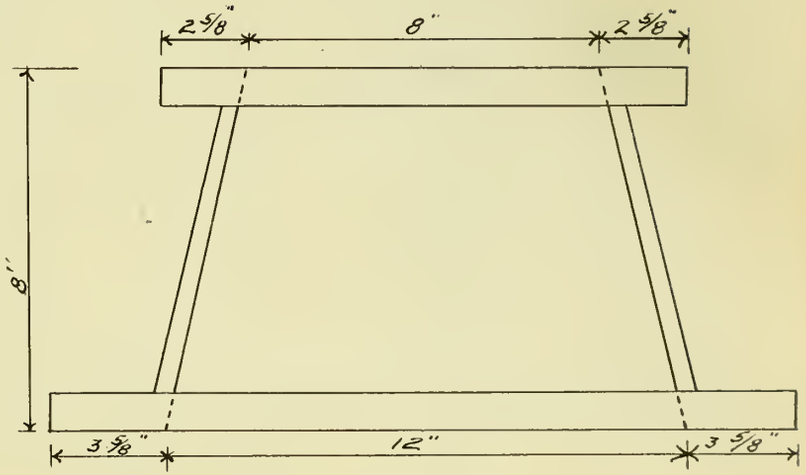


Top Flange Bottom Flange



STEEL BAFFLE

3/4" holes 1" C. To C.



REDUCER

side elevation.

DETAILS FOR 8 IN. JET-REDUCER.

TABLE No 1 a

6 IN ORIFICE ON 12 IN SHORT TUBE

Pit 1 ft rise = Jet $C = Q/1.575 H^{\frac{1}{2}}$

Pit Gage		Time	Disch.	Jet zero = 6.12				Pit Gage		Time	Disch	Jet.			
Init.	Fin.	sec	cu.ft./sec	Rod	Av.	Head	Coef.	Init.	Fin.	sec	cu.ft./sec	Rod	Av.	Head	Coef.
.371				7.51				.624				8.08			
				7.52								8.09			
				7.51								8.08			
				7.51								8.08			
				7.51								8.08			
				7.51								8.09			
				7.51					2.017	179	1.355	8.08	8.08	1.963	.610
				7.51				.427				8.40			
	2.180	280	1.136	7.52	7.51	1.392	.6.12					8.39			
.409				7.49								8.36			
				7.50								8.37			
				7.48								8.36			
				7.49								8.34			
				7.50					2.017	190	1.472	8.35	8.37	2.247	.625
				7.49				.400				8.71			
				7.50								8.70			
				7.50								8.68			
	2.052	257	1.128	7.50	7.50	1.375	.610					8.68			
.437				7.81								8.68			
				7.80								8.67			
				7.80					2.061	189	1.545	8.67	8.68	2.565	.614
				7.80				.456				8.67			
				7.79								8.63			
				7.78								8.64			
				7.78								8.62			
	1.998	219	1.253	7.77	7.79	1.670	.617								

TABLE No 1a.

6 IN ORIFICE ON 12 IN SHORT TUBE

Pit 1 ft rise = Jet $C = Q/1.575 H^{\frac{1}{2}}$

Pit Gage		Time	Disch	Jet zero = 6.12				Pit Gage		Time	Disch	Jet			
Init	Fin	sec.	cu ft/sec	Rod	Av.	Head.	Coef.	Init.	Fin.	sec.	cu ft/sec	Rod	Av.	Head	Coef.
				8.63				.403				9.98			
				8.62								10.00			
				8.62								10.02			
	2.068	182	1.555	8.63	8.63	2.512	.622					10.05			
												10.06			
.463				9.04					2.092	154	1.924	10.07	10.03	3.91	.620
				9.06											
				9.05				.412				10.27			
				9.04								10.28			
				9.04								10.30			
				9.06								10.27			
	2.133	174	1.678	9.05	9.05	2.930	.622					10.34			
									2.175	154	2.004	10.35	10.30	4.18	.625
.452				9.42											
				9.42				.454				7.37			
				9.40								7.36			
				9.38								7.37			
				9.35								7.36			
				9.36								7.37			
	2.070	163	1.741	9.31	9.377	3.217	.619					7.37			
												7.67			
.433				9.63								7.36			
				9.60								7.37			
				9.55								7.36			
				9.55					2.148	271	1.095	7.35	7.36	1.24	.623
				9.62											
	2.099	163	1.790	9.55	9.58	3.462	.612								

TABLE No 1b.

6 IN ORIFICE ON 12 IN SHORT TUBE

Pit 1 ft. rise = Jet $C = Q/1.575\,H^{\frac{1}{2}}$

Pit Gage		Time	Disch	Jet zero = 6.12				Pit Gage		Time	Disch.	Jet			
Init	Fin.	sec.	cu ft/sec.	Rod	Av.	Head	Coef.	Init	Fin	sec	cu ft/sec.	Rod	Av.	Head	Coef.
.542				7.52								8.04			
				7.52								8.04			
				7.51								8.04			
				7.51					2.019	186	1.340	8.04	8.03	1.91	.617
				7.52				.455				8.56			
				7.52								8.57			
				7.52								8.55			
				7.51								8.55			
				7.50								8.53			
				7.51								8.53			
	2.091	234	1.153	7.51	7.51	1.39	.620		2.035	182	1.525	8.54	8.55	2.43	.620
.497				7.79				.458				8.83			
				7.80								8.84			
				7.79								8.86			
				7.80								8.87			
				7.80								8.88			
				7.81								8.89			
				7.81					2.111	177	1.634	8.89	8.87	2.75	.628
				7.81											
				7.81				.455				9.12			
	2.051	212	1.285	7.82	7.80	1.68	.629					9.08			
.586				8.01								9.09			
				8.02								9.07			
				8.02								9.04			
				8.03								9.02			
									2.064	167	1.683	9.02	9.06	2.94	.626

TABLE No 1b.

6 IN ORIFICE ON 12 IN SHORT TUBE

Pit 1 ft. rise = Jet $Q = Q/1.575\,H^{\frac{1}{2}}$

Pit Gage		Time	Disch.	Jet. zero = 6.12				Pit Gage		Time	Disch	Jet			
Init	Fin.	sec.	cuft/sec	Rod	Av.	Head	Coef	Init	Fin	sec.	cuft/sec	Rod	Av.	Head	Coef.
.470				9.42											
				9.41											
				9.38											
				9.38											
				9.40											
	2.088	159	1.786	9.37	9.39	3.27	.627								
.456				9.74											
				9.79											
				9.81											
				9.79											
				9.81											
	2.074	150	1.895	9.82	9.79	3.67	.623								
.459				10.03											
				10.02											
				10.05											
				10.03											
				10.00											
	2.091	147	1.940	10.98	10.02	3.90	.624								
.451				8.31											
				8.30											
				8.32											
				8.32											
				8.30											
				8.31											
	2.087	197	1.450	8.29	8.31	2.19	.624								

TABLE No II a.

8 IN ORIFICE ON 12 IN SHORT TUBE

Pit. 1 ft rise = Jet $C = Q/1.575\ H^{\frac{1}{2}}$

Pit Gage		Time	Disch	Jet zero = 6.085				Pit Gage		Time	Disch	Jet			
Init	Fin	sec.	cu ft/sec	Rod	Av.	Head	Coef.	Init	Fin	sec.	cu ft/sec	Rod	Av.	Head	Coef.
.498				7.42				.491				8.34			
				7.42								8.34			
				7.42								8.32			
				7.41								8.34			
	2.120	142	1.996	7.41	7.42	1.33	.620					8.34			
									1.985	102	2.560	8.33	8.33	2.25	.634
.412				7.56											
				7.57				.476				8.57			
				7.57								8.56			
				7.60								8.55			
				7.57								8.55			
				7.58					2.152	104	2.814	8.53	8.55	2.47	.644
				7.58											
	2.130	139	2.170	7.58	7.58	1.49	.636	.510				8.86			
												8.87			
.472				7.76								8.87			
				7.78								8.88			
				7.75					2.300	107	2.925	8.90	8.87	2.79	.627
				7.78				486				9.18			
				7.76								9.15			
	2.124	126	2.318	7.73	7.76	1.67	.636					9.13			
.466				8.06					2.040	88	3.095	9.14	9.15	3.06	.636
				8.08											
				8.07											
				8.09											
				8.06											
	2.147	118	2.494	8.06	8.07	2.98	.634								

TABLE No II a.

8 IN ORIFICE ON 12 IN SHORT TUBE

Pit. 1 ft rise = Jet C = Q/13

Pit gage		Time	Disch	Jet zero = 6.085				Pit Gage		Time	Disch	Jet			
Init	Fin	sec.	cu ft/sec.	Rod	Av.	Head	Coef.	Init	Fin	sec	cu ft/sec	Rod	Av.	Head	Coef.
503				9.48				.407				10.26			
				9.50								10.27			
				9.53								10.29			
				9.55								10.26			
	2.109	85	3.310	9.53	9.52	3.43	.638		2.087	80	3.690	10.32	10.28	4.19	.645
.407				9.69				.402				9.15			
				9.67								9.13			
				9.67								9.14			
				9.69								9.14			
				9.65					2.101	94	3.170	9.14	9.14	3.05	.647
	2.101	86	3.460	9.68	9.67	3.59	.652								
								409				8.92			
.415				9.95								8.87			
				9.95								8.88			
				9.98								8.90			
				9.97					2.136	100	3.030	8.90	8.89	2.81	.643
	2.165	86	3.555	9.97	9.97	3.88	.646								
.410				10.16											
				10.30											
				10.25											
				10.27											
	2.137	82	3.705	10.23	10.24	4.15	.648								

PLATE No II b.

8 IN ORIFICE ON 12 IN SHORT TUBE

Pit 1 ft. rise = Jet C = Q

Pit Gage		Time	Disch	Jet zero = 6.085				Pit Gage		Time	Disch	Jet.			
Init	Fin.	sec	cu.ft./sec	Rod	Av.	Head	Coef.	Init.	Fin.	sec	cu.ft./sec	Rod	Av.	Head	Coef.
.433				7.48				.378				8.54			
				7.47								8.53			
				7.48								8.53			
				7.49								8.52			
				7.48					1.954	100	2.785	8.53	8.53	2.43	.638
				7.48											
	2.064	136	2.105	7.48	7.48	1.39	.636	.410				8.62			
												8.60			
.455				7.62								8.60			
				7.63								8.58			
				7.63								8.58			
				7.62					1.995	98	2.850	8.57	8.59	2.49	.647
				7.61											
				7.63				.393				8.88			
	2.045	127	2.195	7.62	7.62	1.53	.638					8.90			
												8.88			
.440				7.89								8.87			
				7.88					1.992	.94	3.000	8.89	8.88	2.78	.642
				7.88											
				7.88				.398				9.24			
	2.064	121	2.355	7.89	7.88	1.80	.628					9.24			
												9.26			
.358	×			8.17								9.26			
				8.20					2.087	.93	3.175	9.25	9.25	3.15	.635
				8.18											
				8.17				.395				9.44			
												9.43			
	1.880	103	2.610	8.18	8.18	2.08	.647					9.39			

TABLE No II b.

8 IN ORIFICE ON 12 IN SHORT TUBE.

Pit 1 ft. rise = Jet C = Q

Pit Gage		Time	Disch	Jet zero = 6.085				Pit Gage		Time	Disch	Jet			
Init	Fin.	sec.	cu ft/sec	Rod	Av.	Head	Coef.	Init.	Fin	sec.	cu ft/sec	Rod	Av.	Head	Coef.
				9.42											
	2.037	87	3.320	9.36	9.40	3.30	.650								
.405				9.72											
				9.72											
				9.74											
				9.73											
	2.107	86	3.435	9.74	9.73	3.63	.646								
.377				10.02											
				10.03											
				10.08											
				10.08											
	2.045	82	3.565	10.04	10.04	3.94	.644								
.390				10.24											
				10.24											
				10.22											
				10.18											
	2.050	80	3.660	10.22	10.22	4.12	.646								
.390				10.16											
				10.18											
				10.17											
				10.20											
	2.053	80	3.670	10.25	10.19	4.09	650								

TABLE No III

4 IN ORIFICE ON 12 IN SHORT TUBE

Pit 1 ft rise = Jet C = Q

Pit Gage		Time	Disch	Jet zero = 6.07				Pit Gage		Time	Disch	Jet			
Init.	Fin.	sec	cu ft/sec	Rod	Av.	Head	Coef.	Init	Fin	sec	cu ft/sec	Rod	Av.	Head	Coef.
.446				7.57				.633				8.94			
				7.56								8.91			
				7.56								8.90			
				7.57								8.91			
	1.152	244	.506	7.57	7.57	1.50	.594					8.90			
									1.531	223	.674	8.89	8.91	2.84	.569
.505				7.70											
				7.70				.747				9.03			
				7.70								9.03			
				7.70								9.02			
	1.266	254	.521	7.69	7.70	1.63	.582					9.01			
												9.01			
.507				7.97								9.02			
				7.97					1.492	248	.717	9.01	9.02	2.95	.598
				7.97											
				7.96				.474				9.11			
				7.96								9.12			
	1.404	277	.567	7.96	7.97	1.90	.585					9.12			
												9.12			
.822				8.32								9.12			
				8.34								9.12			
				8.33					1.531	251	.737	9.12	9.12	3.05	.603
				8.33											
	1.609	219	.632	8.32	8.33	2.26	.602	.614				9.46			
												9.48			
1.237				8.62								9.46			
				8.62								9.43			
				8.63								9.42			
	2.098	225	.670	8.64	8.63	2.56	.600								

TABLE No III

4 IN ORIFICE ON 12 IN SHORT TUBE

Pit. 1 ft rise = Jet C = Q

Pit Gage		Time	Disch	Jet zero = 6.07				Pit Gage		Time	Disch	Jet			
Init	Fin	sec.	cu ft sec	Rod	Av.	Head	Coef.	Init	Fin.	sec.	cu ft sec	Rod	Av.	Head	Coef.
				9.42								10.32			
	1.615	227	.767	9.41	9.44	3.37	.600		1.835	242	.861	10.26	10.25	4.18	.601
.625				9.75				.513				10.24			
				9.76								10.13			
				9.75								10.10			
				9.78								10.11			
				9.78								10.12			
	1.603	211	.808	9.77	9.77	3.70	.594					10.13			
.774				10.00								10.13			
				9.98					1.893	287	.848	10.12	10.14	4.06	.600
				9.97				.519				10.22			
				9.95								10.23			
				9.95								10.22			
	1.610	178	.824	9.94	9.97	3.90	.599					10.23			
.814	+6			10.34								10.21			
				10.37								10.22			
				10.39								10.20			
				10.41								10.22			
				10.43								10.23			
	1.681	173	.871	10.41	10.39	4.32	.601					10.21			
									1.953	300	.840	10.22	10.22	4.15	.582
.639				10.42											
				10.40											
				10.36											
				10.33											
				10.33											

TABLE NO IV

3 IN ORIFICE ON 12 IN SHORT TUBE

Pit 1ft rise =

Pit Gage		Time	Disch	Jet zero = 6.07				Pit Gage		Time	Disch	Jet			
Init	Fin.	sec	cuft/sec	Rod	Av.	Head	Coef.	Init	Fin	sec	cuft/sec	Rod	Av.	Head	Coef.
.503				7.78								8.55			
				7.79								8.56			
				7.77								8.56			
				7.76					.980	270	.373	8.57	8.56	2.49	.600
	.910	235	.298	7.76	7.77	1.70	.583	.981				8.90			
.913				7.88								8.90			
				7.87								8.90			
				7.88								8.89			
				7.87								8.89			
				7.88					1.514	238	.393	8.91	8.90	2.83	.598
				7.88				1.514				9.20			
				7.88								9.19			
				7.89								9.18			
	1.436	297	.308	7.90	7.88	1.81	.585					9.18			
1.437				8.27								9.19			
				8.28					2.065	237	.409	9.20	9.19	3.12	.586
				8.26				.543				9.53			
				8.26								9.54			
				8.25								9.52			
				8.24								9.51			
				8.22					1.080	215	.431	9.50	9.52	3.45	.596
	2.108	348	.346	8.21	8.25	2.18	.585	1.081				9.78			
.913				8.55								9.79			
				8.54								9.80			
				8.55								9.78			

TABLE No IV

3 IN ORIFICE ON 12 IN SHORT TUBE

Pit 1ft rise =

Pit Gage		Time	Disch	Jet zero = 6.07				Pit Gage		Time	Disch	Jet			
Init	Fin	sec.	cu.ft.sec	Rod	Av.	Head	Coef	Init	Fin	sec	cu.ft.sec	Rod	Av.	Head	Coef.
				9.77								10.57			
				9.75					1.854	240	.492	10.58	10.55	4.48	.596
				9.73				.264				8.20			
				9.71								8.20			
	2.089	395	.444	9.70	9.75	3.69	.594					8.20			
.480				10.06								8.20			
				10.08								8.20			
				10.07								8.21			
				10.07								8.20			
	1.119	239	.467	10.08	10.07	4.00	.593		.886	338	.326	8.21	8.20	2.13	.573
1.119				10.32				.886				9.13			
				10.26								9.14			
				10.25								9.15			
				10.23								9.16			
	1.760	239	.471	10.21	10.25	4.18	.588					9.17			
.350				10.45								9.19			
				10.47								9.20			
				10.49					1.657	335	.404	9.22	9.17	3.10	.583
				10.99				.402				9.20			
				10.50								9.19			
				10.50								9.18			
	1.182	301	.488	10.45	10.48	4.41	.592					9.17			
1.182				10.51								9.16			
				10.54								9.15			
				10.55								9.15			

TABLE No IV
3 IN ORIFICE ON 12 IN SHORT TUBE

Pit 1 ft. rise = Jet C = Q

Pit Gage		Time	Disch	Jet zero = 6.07				Pit Gage		Time	Disch	Jet			
Init.	Fin	sec	cu.ft.sec	Rod	Av.	Head	Coef	Init	Fin	sec	cu.ft.sec	Rod	Av.	Head	Coef.
				9.16				.333				7.83			
				9.15								7.84			
				9.14								7.84			
	1.379	415	.414	9.13	9.16	3.09	.597					7.84			
												7.84			
1.379				7.78								7.83			
				7.79								7.82			
				7.77								7.82			
				7.77								7.82			
				7.77								7.81			
				7.79								7.81			
				7.79								7.82			
				7.81					1.876	900	.303	7.83	7.83	1.75	58.3
				7.82											
	2.059	398	.302	7.83	7.79	1.72	.584	406				8.83			
												8.24			
.293				10.46								8.23			
				10.44								8.23			
				10.42								8.24			
				10.41								8.24			
				10.41								8.35			
				10.42								8.26			
				10.43								8.27			
				10.46								8.28			
				10.48								8.28			
	1.820	557	.479	10.48	10.44	4.37	.580					8.31			
												8.31			
									1.992	780	.359	8.29	8.27	2.19	.617

TABLE No IV
3 IN ORIFICE ON 12 IN SHORT TUBE

Pit 1 ft. rise = Jet C = Q

Pit Gage		Time	Disch	Pit Jet zero = 6.07				Pit. Gage		Time	Disch	Jet			
Init	Fin	sec	cu ft sec	Rod	Av.	Head	Coef	Init	Fin	sec	cu ft sec.	Rod	Av.	Head	Coef
.432				8.84								9.83			
				8.87								9.84			
				8.87								9.82			
				8.89								9.82			
				8.89					1.902	533	.457	9.84	9.84	3.76	.600
				8.87				.435				10.45			
				8.86								10.43			
				8.85								10.40			
				8.83								10.36			
				8.81								10.32			
				8.80								10.30			
	2.076	716	.403	8.79	8.75	2.68	.628					10.47			
												10.44			
.385				9.49											
				9.49					1.964	549	.491	10.42	10.40	4.32	.602
				9.50				.398				8.18			
				9.49								8.18			
				9.48								8.18			
				9.47								8.17			
				9.47								8.17			
				9.47								8.17			
	2.043	656	.447	9.47	9.48	3.40	.613					8.17			
.510				9.90								8.16			
				9.86								8.15			
				9.85								8.14			
				9.83					2.004	835	.336	8.14	8.16	2.08	.596
				9.83											

TABLE No V

COMPARISON 8 IN JET AND 3 FT. WEIR

0 Head Rod – 6.075 | 0 Head Gage 1.044

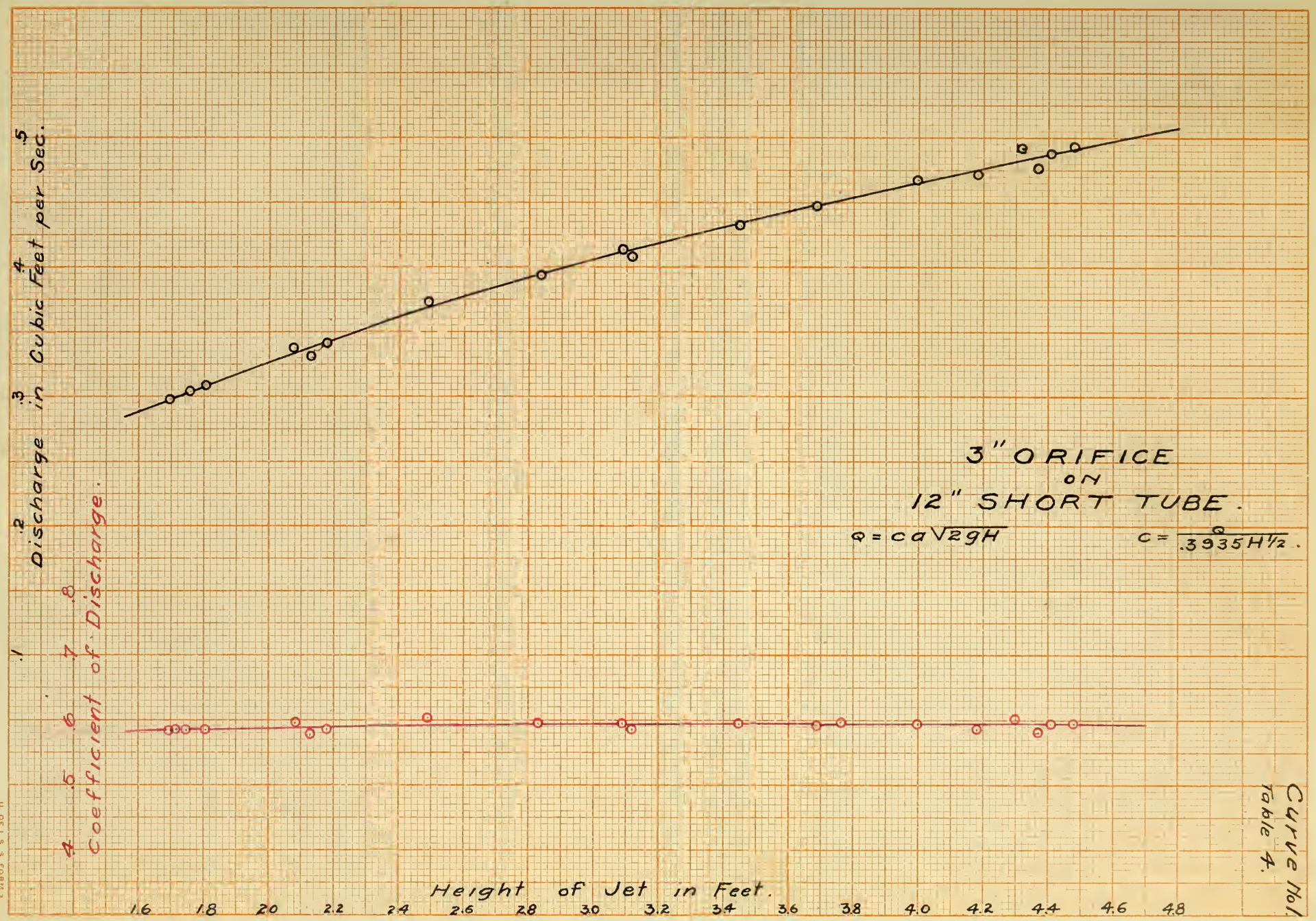
Jet Rod	Jet Av	Actual	Disch cu.ft.sec	Weir Gage	Weir Av.	Actual	Disch cu.ft.sec.	Jet Rod	Jet Av.	Actual	Disch. cu.ft.sec	Weir Gage	Weir Av	Actual	Disch. cu.ft sec
Readings taken at 1 min. intervals															
6.54				1.405				9.05				1.507			
6.54				1.405				9.09				1.506			
6.55				1.404				9.11				1.506			
6.55				1.407				9.09				1.506			
6.56	6.55	1.48	2.16	1.406	1.405	.361	2.14	9.12	9.09	301	3.11	1.507	1.507	.463	3.10
7.83				1.431				9.51				1.532			
7.85				1.430				9.52				1.529			
7.86				1.430				9.54				1.532			
7.85				1.428				9.58				1.531			
7.84	7.85	1.77	2.36	1.430	1.430	.386	2.36	9.60	9.50	3.48	3.36	1.531	1.531	.487	3.32
8.28				1.461				10.01				1.553			
8.29				1.461				10.00				1.553			
8.29				1.462				9.97				1.553			
8.29				1.463				10.00				1.553			
8.30	829	2.22	2.65	1.461	1462	418	2.65	9.97	9.99	8.91	3.58	1.552	1553	.509	3.55
8.61				1.482				10.29				1.564			
8.59				1.482				10.30				1.564			
8.58				1.481				10.31				1.565			
8.57				1.481				10.33				1566			
8.57	8.58	2.51	2.83	1.480	1.481	.437	2.83	10.36	10.32	4.25	3.74	1566	1.565	5.21	3.78

TABLE No VI

10 IN ORIFICE ON 12 IN SHORT TUBE

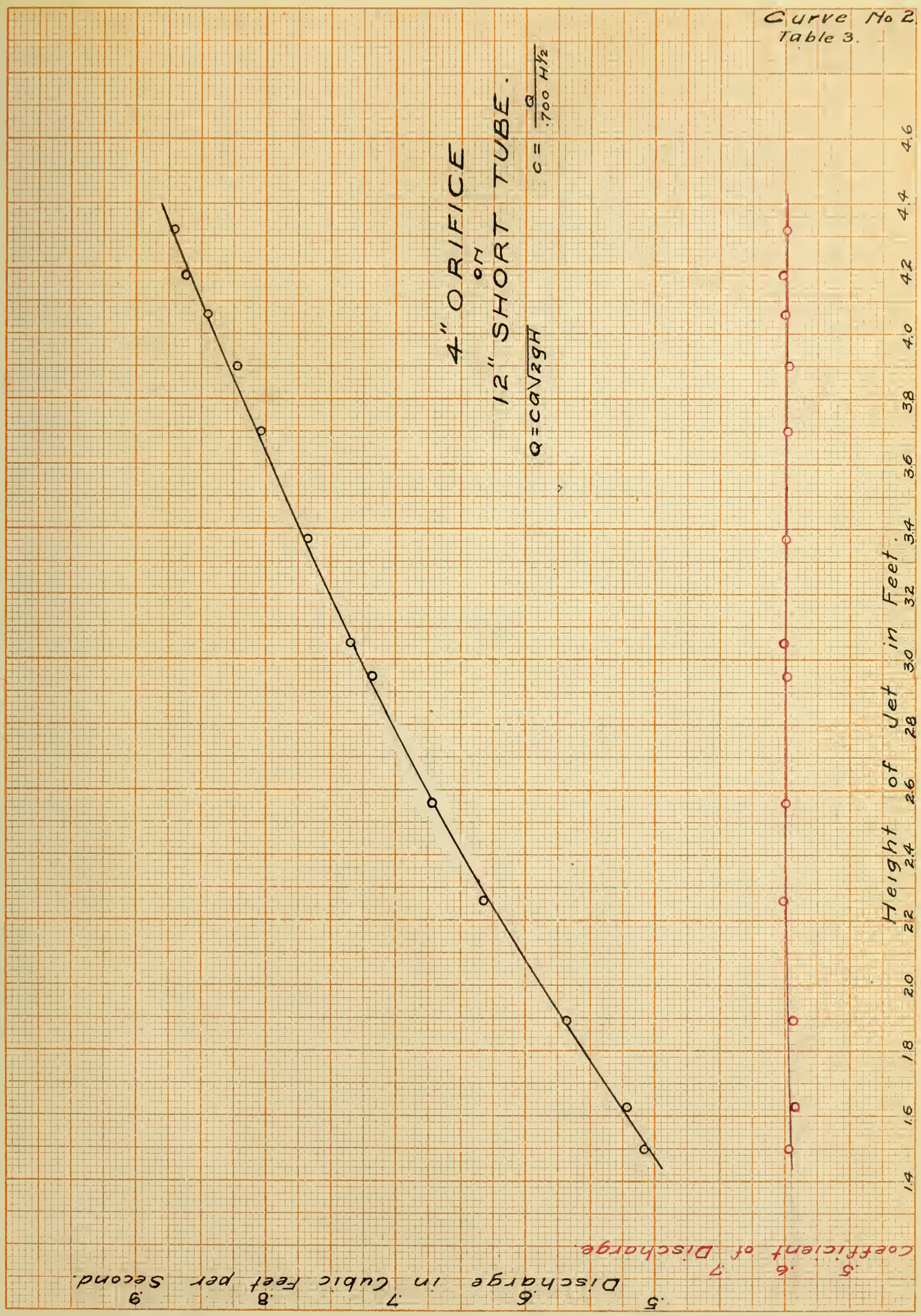
ö Head Rod 6.09 — ö Head Gage 10.44

Jet Rod	Jet Av.	Actual	Disch cu.ft.sec	Weir Gage	Weir Av	Actual	Disch cu.ft.sec.	Jet Rod	Jet Av	Actual	Disch cu.ft.sec	Weir Gage	Weir Av	Actual	Disch cu.ft.sec.
Readings taken at 1 min. intervals															
7.38				1.542				8.61				1.674			
7.39				1.541				8.60				1.672			
7.38				1.542				8.63				1.672			
7.38				1.542				8.63				1.672			
7.38	7.38	1.29	3.43	1.541	1.541	.497	3.43	8.58	8.61	2.52	4.82	1.670	1.672	.678	4.82
					coef	.689							coef.	.693	
7.72				1.584				9.00				1.703			
7.73				1.585				9.04				1.703			
7.72				1.585				9.02				1.702			
7.72				1.584				9.00				1.702			
7.73	7.72	1.63	3.87	1.584	1.584	.540	3.87	9.02	9.01	2.92	5.17	1.701	1.702	.658	.517
					coef	.694							coef	.691	
8.02				1.615				9.13				1.718			
8.05				1.618				9.16				1.718			
8.04				1.619				9.17				1.718			
8.07				1.620				9.16				1.717			
8.08	8.05	1.96	4.25	1.621	1.619	.575	4.25	9.18	09.16	3.07	5.35	1.717	1.717	.673	5.35
					coef.	.693							coef	.697	
8.41				1.654				6.93				1.460			
8.40				1.653				6.91				1.458			
8.44				1.654				6.90				1.456			
8.43				1.654				6.90				1.456			
8.46	8.43	2.34	4.61	1.657	1.654	.610	4.61	6.88	6.90	0.81	2.60	1.454	1.456	.412	2.60
					coef	.689							coef.	.660	



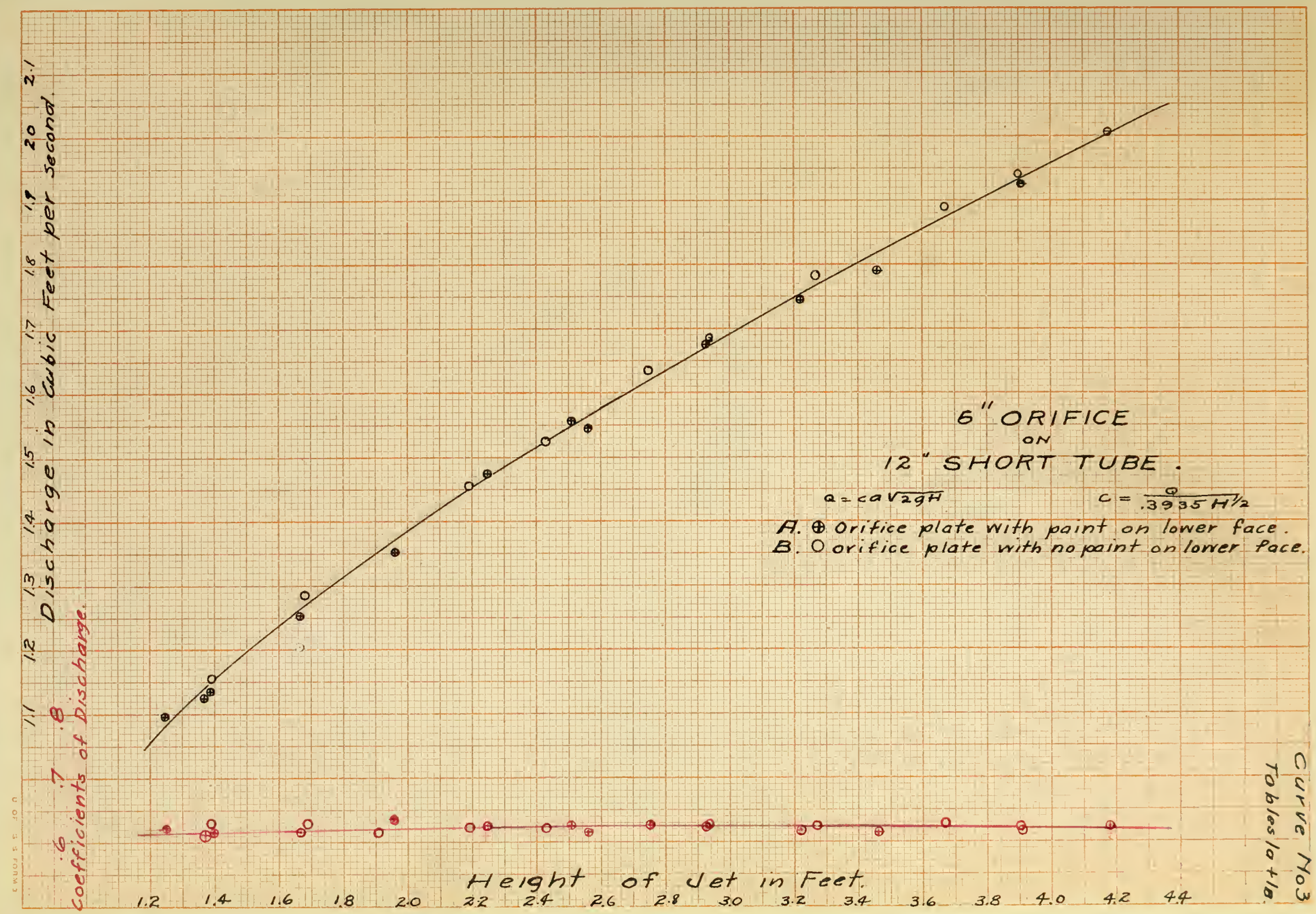
Curve No. 1
Table 4.

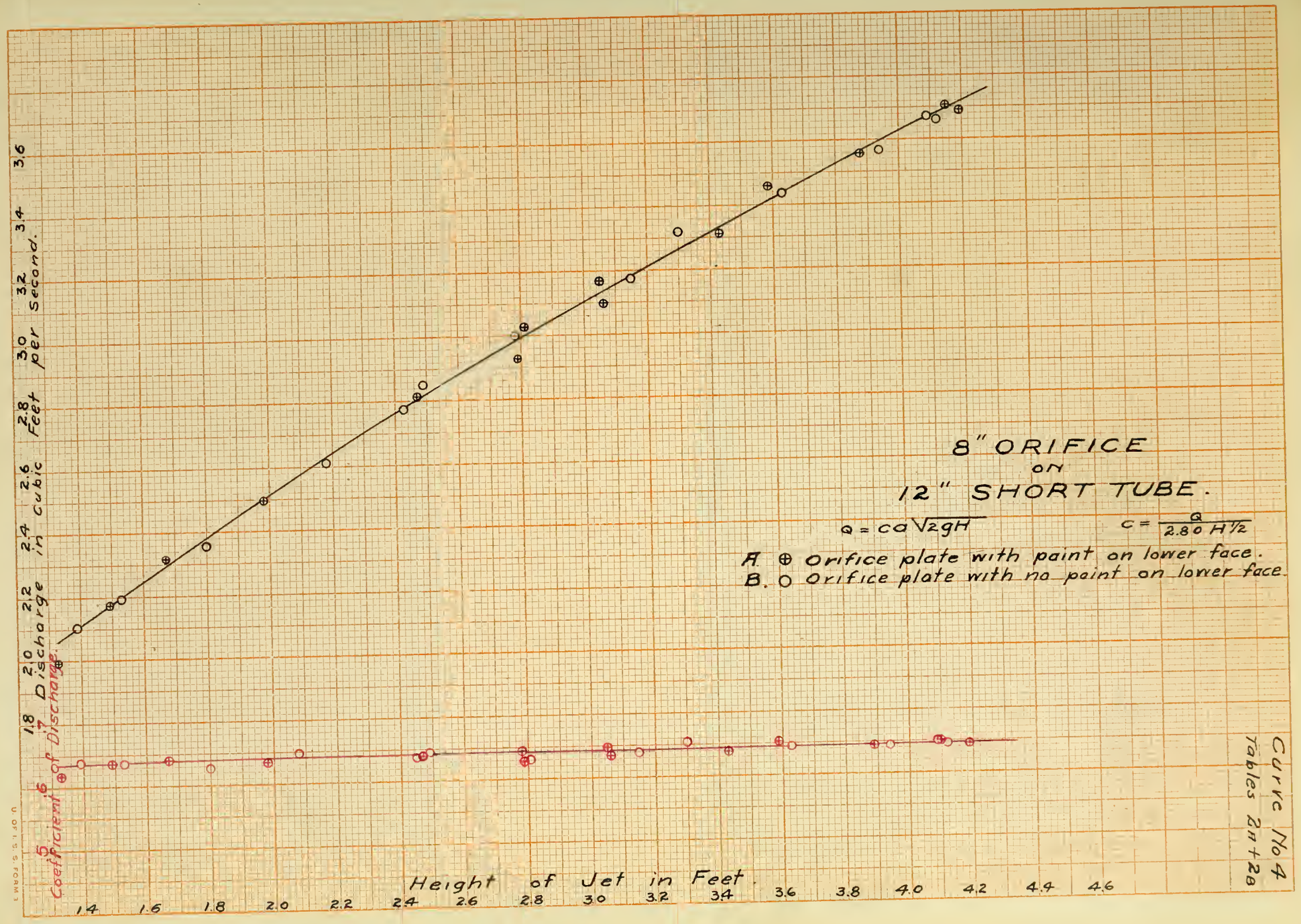
U. OF I. S. S. FORM 3



U. OF I. S. S. FORM 3

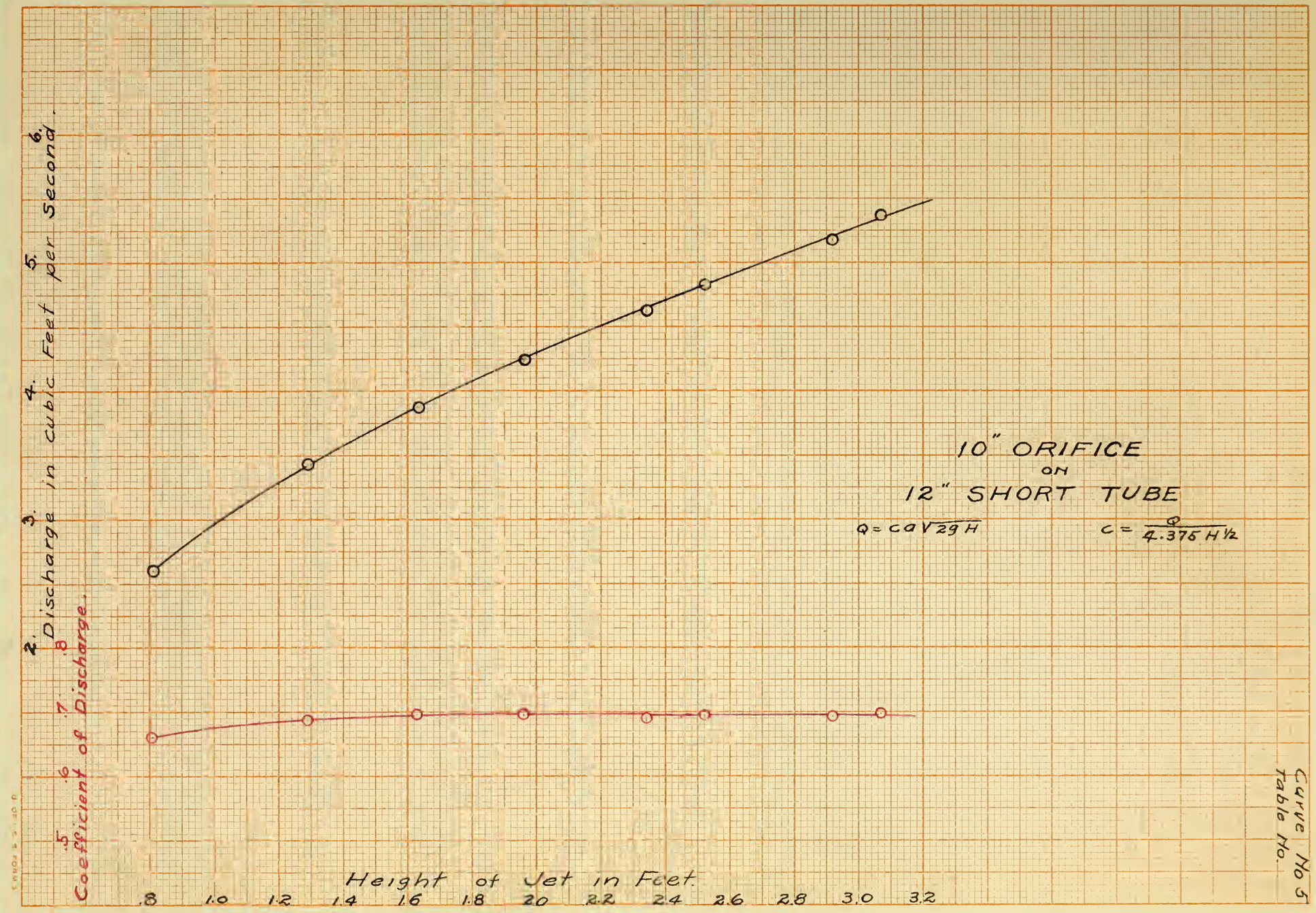
Curve No 3
Tables 10 to 18.



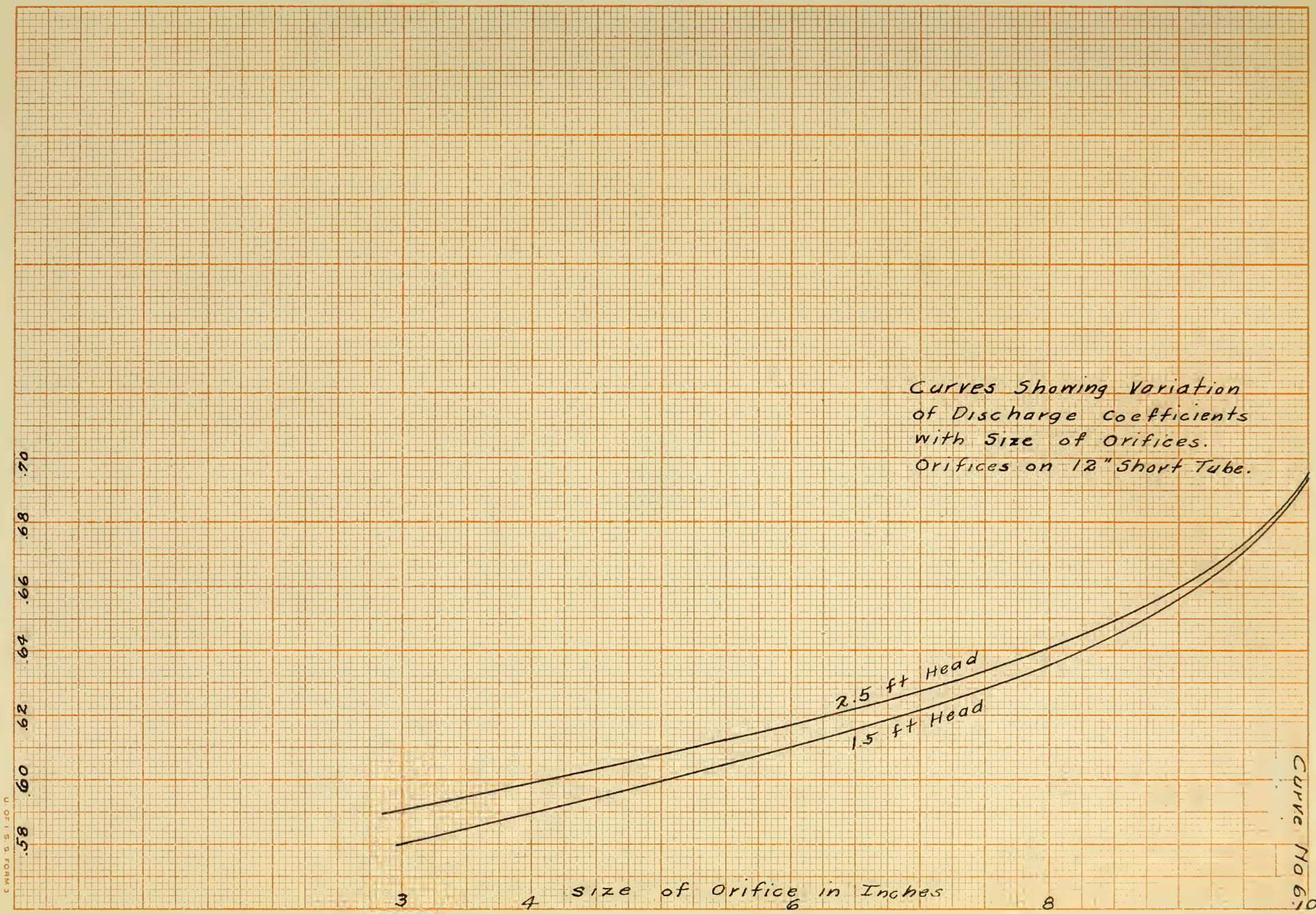


Curve No 4
Tables 2nt 28

U. OF I. S. FORM 3



Curve No 5
Table No.



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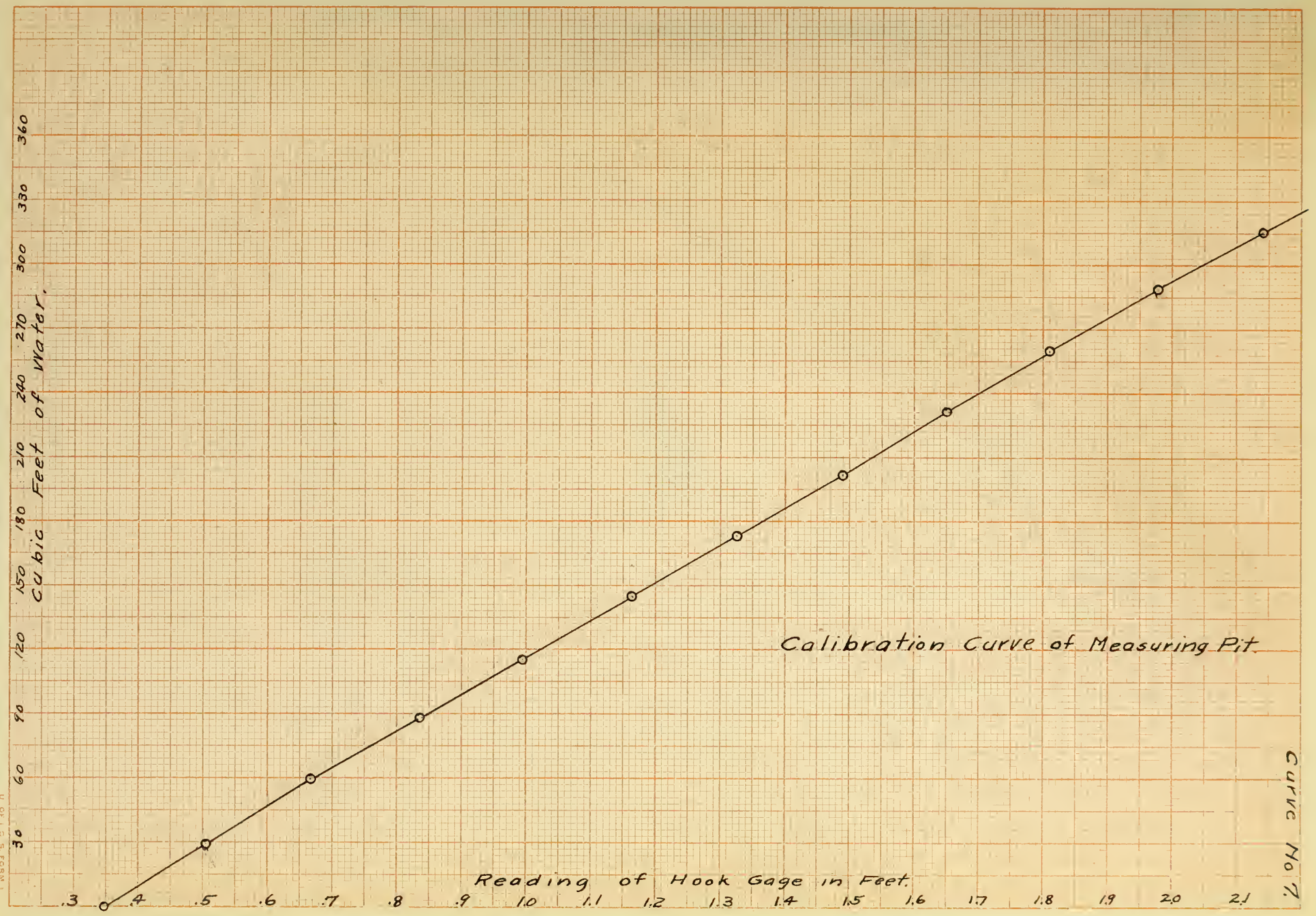
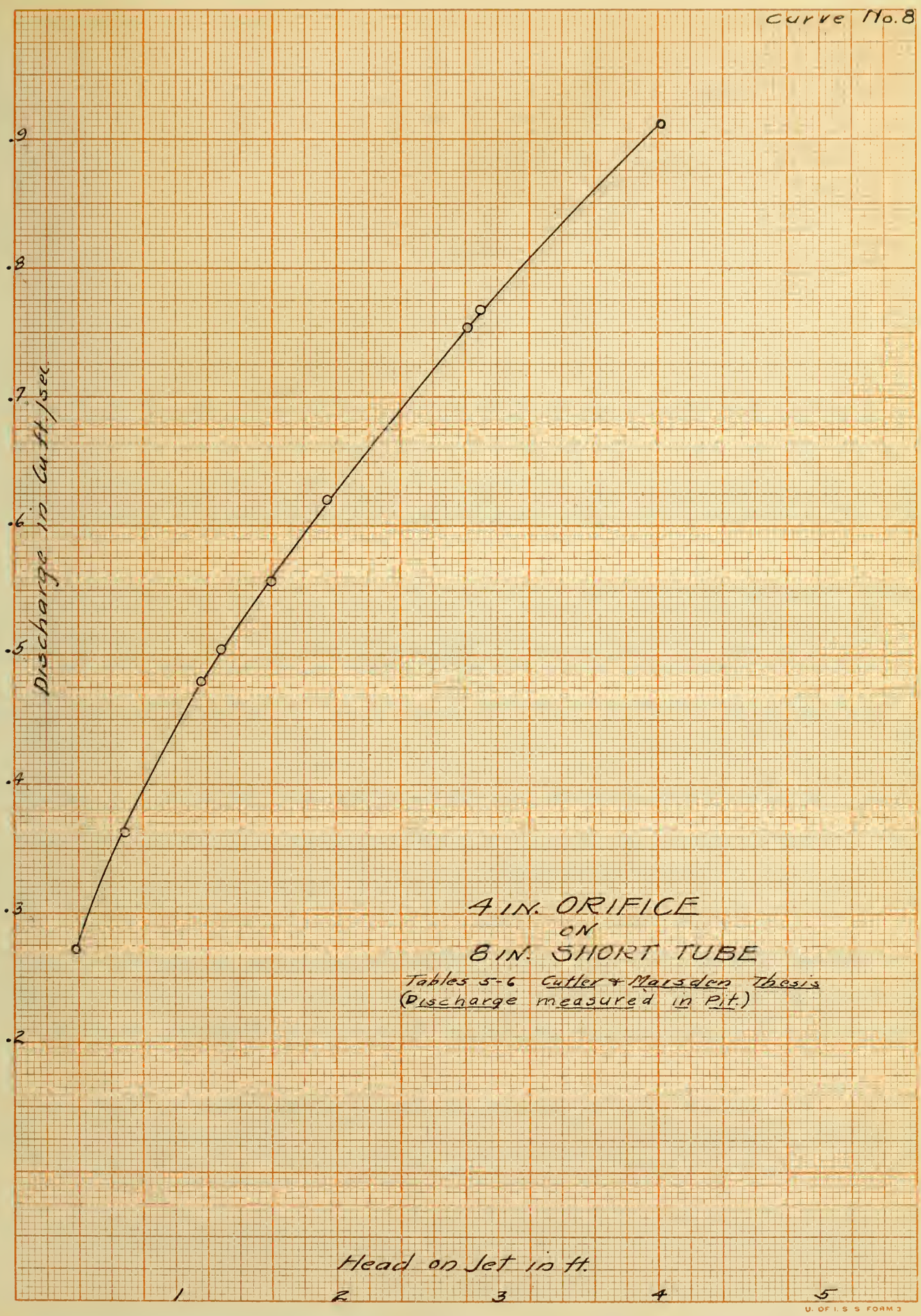

Calibration Curve of Measuring Pit.
Cubic Feet of Water.
30
60
90
120
150
180
210
240
270
300
330
360
Reading of Hook Gage in Feet.
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1

Curve No. 7.



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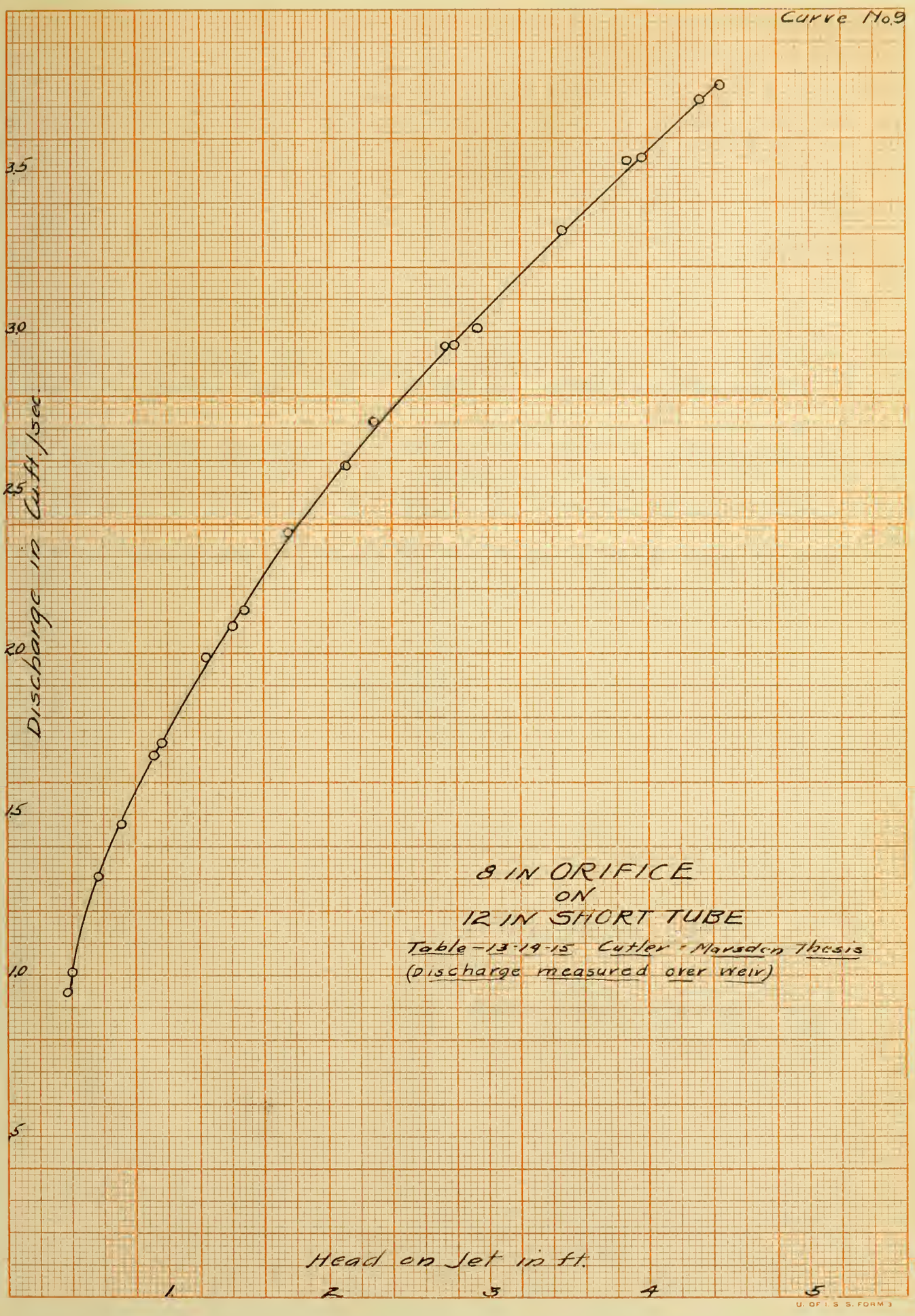

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